Analysis of occupants' behavior related to the use of windows in German households

Real energy performances of buildings depend not only on deterministic aspects, such as building physics and HVAC systems, but also on stochastic aspects such as weather and occupants' behavior. Typically, occupant behavior is not adequately considered when calculating the expected performance. As a result, field test studies all over Europe have shown discrepancies between real and expected energy performance of buildings. In order to bridge this gap, stochastic occupants' behavior models could be embedded into building energy performance simulation software. In order to make such models, there is a need for a better understanding of occupants' behavior and in particular the reasons of their adjustments of building controls such as window opening, heating set points, etc. The purpose of this paper was to analyze window opening behavior in residential buildings, investigate which drivers lead occupants to interact with windows and how these actions can be modeled. A method to analyze the probability of a state change of the windows, based on logistic regression, was applied to monitored data (measured each minute) from two refurbished demonstration buildings. The weather and the five rooms of the 60 apartments located in the buildings were monitored in terms of air quality and thermal environment (presence of occupants was not monitored) during four years. The most common driver to open a window was the time of the day, followed by the carbon dioxide concentration. The most common driver to close a window was the daily average outdoor temperature, followed by the time of the day. (C) 2016 Elsevier Ltd. All rights reserved.

General information
State: Published
Organisations: Department of Civil Engineering, Section for Indoor Climate and Building Physics, RWTH Aachen University
Number of pages: 16
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Energy performance gap in refurbished German dwellings: Lessons learned from a field test

Low insulation standards and obsolete heating systems of a large amount of buildings in Europe account for disproportional energy consumption. Within this project, the holistic renovation and the results from the monitoring activity of buildings from a field test, located in Southern Germany, are presented. The buildings, built at the end of the 1950s, have been retrofitted with seven different refurbishment layouts. The layouts differ in insulation and engineering system. An installed monitoring system collects thermal indoor environmental conditions and air quality conditions in rooms, as well as data about energy flows at delivery, distribution, storage and generation level, at high time resolution. The monitoring system allows a comparison between the real and the expected energy consumption of the buildings. The energy performance gap was identified and quantified for each refurbishment solution (with values up to 287% based on calculated savings): on average, the energy performance gap of the entire field test varied from 117% in 2011, 107% in 2012, 41% in 2013 and 60% in 2014. The occupants’ behavior has been identified as one of the causes for the energy performance gap. Further causes are mistakes in the installation, and malfunctioning of the engineering system. The importance of a monitoring system for buildings with a complex engineering system was confirmed.
Modelling diversity in building occupant behaviour: a novel statistical approach

We propose an advanced modelling framework to predict the scope and effects of behavioural diversity regarding building occupant actions on window openings, shading devices and lighting. We develop a statistical approach based on generalised linear mixed models to account for the longitudinal nature of observations on occupants, and to provide a coherent method to capture observed variability amongst occupant/room pairings through built-in probabilistic terms describing occupant diversity in a tractable manner within building energy simulation. The contribution of the proposed method is demonstrated using collected behavioural data from three long-term monitoring campaigns (an office building in Switzerland and residential units in Germany and Denmark).
Occupants’ Behavior and its Impact upon the Energy Performance of Buildings

General information
State: Published
Organisations: RWTH Aachen University
Authors: Calì, D. (Intern)
Publication date: 2016

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Original language: German
Main Research Area: Technical/natural sciences
Source: Bibtex
Source-ID: urn:94e1db18d2a2f735d7cb8e6df7171a33
Publication: Research › Doctoral thesis – Annual report year: 2016

CO2 based occupancy detection algorithm: Experimental analysis and validation for office and residential buildings

General information
State: Published
Organisations: RWTH Aachen University
Authors: Calì, D. (Intern), Matthes, P. (Ekstern), Huchtemann, K. (Ekstern), Streblow, R. (Ekstern), Müller, D. (Ekstern)
Number of pages: 11
Pages: 39-49
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Scopus rating (2016): CiteScore 4.51 SJR 2.015 SNIP 2.198
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Scopus rating (2015): SJR 2.093 SNIP 2.49 CiteScore 4.37
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.938 SNIP 2.797 CiteScore 4.14
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.581 SNIP 2.602 CiteScore 3.57
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.331 SNIP 2.875 CiteScore 3.06
Entwicklung von Modellkomponenten der Lüftungstechnik zur dynamischen Simulation des Heizwärmebedarfs von Wohngebäuden

General information
State: Published
Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Bertinelli, M. (Ekstern), Streblow, R. (Ekstern), Müller, D. (Ekstern)
Number of pages: 10
Pages: 230-239
Publication date: 2015

Host publication information
Title of host publication: Gebäudetechnik, Innenraumklima
Main Research Area: Technical/natural sciences
Source: Bibtex
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Publication: Research - peer-review » Article in proceedings – Annual report year: 2015

Ergebnisse einer energetischen Sanierung: Abweichung zwischen Energiebedarf und Verbrauch – ist nur der Nutzer Schuld?

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EVALUATION OF DIFFERENT ENERGY-EFFICIENT REFURBISHMENTS

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Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Cali, D. (Intern), Streblow, R. (Ekstern), Müller, D. (Ekstern)
Publication date: 2015

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Title of host publication: CISBAT 2015 International Conference Future Buildings + Districts, Sustainability from nano to urban scale
Main Research Area: Technical/natural sciences
Source: Bibliothek
Source-ID: urn:1174ca445a695623f762df2c90c8e525
Publication: Research - peer-review › Journal article – Annual report year: 2015

Grenzen des Energieeinsparpotentials energetischer Sanierungen bei Bestandswohngebäuden

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Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Cali, D. (Intern), Streblow, R. (Ekstern), Müller, D. (Ekstern)
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Relevanz von Nutzungseinflüssen auf die tatsächliche Effizienz von energetischen Sanierungsmaßnahmen

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Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Streblow, R. (Ekstern), Müller, D. (Ekstern)
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Rebound-Effekt bei der Sanierung von Bestandsgebäuden: IK Bau

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Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Streblow, R. (Ekstern), Müller, D. (Ekstern)
Publication date: 2014
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Source: Bibtex
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Verringertes Einsparpotential bei Wohngebäuden der 50er Jahre: der Rebound-Effekt?

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Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Streblow, R. (Ekstern), Müller, D. (Ekstern)
Number of pages: 5
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Journal: Sanitär- + Heizungstechnik : SHT
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Advanced Renovation of three Residential Buildings – Evaluation of a Field Test: Contribution to a conference proceedings

General information
State: Published
Extensive Renovation of three Residential Buildings: Monitoring of a Field Test: Contribution to a conference proceedings

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Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Streblow, R. (Ekstern), Müller, D. (Ekstern)
Publication date: 2013

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Title of host publication: CLIMA 2013: 11th REHVA World Congress 8th International Conference on IAQVEC; „Energy Efficient, Smart and Healthy Buildings"
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Main Research Area: Technical/natural sciences
Source: Bibtex
Source-ID: urn:8523dfb2474dd7f9507f339073840a1
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

Ganzheitliche Sanierung und Monitoring für Bestandswohngebäude der 1950/60er Jahre: Contribution to a conference proceedings

General information
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Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Müller, D. (Ekstern)
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Holistic Renovation and Monitoring of Residential Buildings: Contribution to a conference proceedings

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State: Published
Organisations: RWTH Aachen University
Authors: Calì, D. (Intern), Streblow, R. (Ekstern), müller, D. (Ekstern), Osterhage, T. (Ekstern)
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Title of host publication: Rethink, renew, restart: ECEEE 2013 summer study; conference proceedings
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Monitoring of a Renovated Residential Building and Simulative Investigation of Optimization Potential

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Organisations: RWTH Aachen University
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Rebound-Effekt: Saniert verbraucht mehr als kalkuliert

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Main Research Area: Technical/natural sciences

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Journal: Der Facility-Manager: Gebäude und Anlagen besser planen, bauen, bewirtschaften
Issue number: 20
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Evaluation baukonstruktiver und anlagentechnischer Sanierungsmaßnahmen für Bestandswohngebäude

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Title of host publication: DKV - Deutsche Kälte-Klima Tagung 2012
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Multi-Physics Test Bed for Renewable Energy Systems in Smart Homes

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**New Energy Concepts and Related Information Technologies : Dual Demand Side Management: Contribution to a conference proceedings**

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Organisations: RWTH Aachen University
Authors: Molitor, C. (Ekstern), Calì, D. (Intern), Streblow, R. (Ekstern), Ponci, F. (Ekstern), Müller, D. (Ekstern)
Publication date: 2012

**Host publication information**
Title of host publication: ISGT 2012 - IEEE PES Innovative Smart Grid Technologies
Series: ISGT 2012 - IEEE PES Innovative Smart Grid Technologies
Main Research Area: Technical/natural sciences
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Source-ID: urn:b7190d2c0f9d451652e161ce82bca681
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Organisations: RWTH Aachen University
Authors: Müller, D. (Ekstern), Osterhage, T. (Ekstern), Calì, D. (Intern)
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Main Research Area: Technical/natural sciences
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**Different Strategies For Refurbishment: Contribution to a conference proceedings**

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Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Müller, D. (Ekstern)
Publication date: 2011

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Title of host publication: CISBAT 2011: Cleantech for sustainable buildings ; from nano to urban scale : proceedings
Main Research Area: Technical/natural sciences
Source: Bibtex
Source-ID: urn:a6367e8720665d15e4fe7265c6733d66
Publication: Research - peer-review › Article in proceedings – Annual report year: 2011

**Evaluation von Sanierungsmaßnahmen für Wohngebäude der 50/60er Jahre**

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Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Müller, D. (Ekstern)
Publication date: 2011

**Host publication information**
Title of host publication: ARGE Erneuerbare Energie
Methodische Untersuchung von Sanierungsmaßnahmen für Wohngebäude der 50-er Jahre

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State: Published
Organisations: RWTH Aachen University
Authors: Osterhage, T. (Ekstern), Calì, D. (Intern)
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Title of host publication: Ökosan ’11 : Internationale Konferenz für hochwertige energetische Sanierung von großvolumigen Gebäuden
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Main Research Area: Technical/natural sciences
Source: Bibtex
Source-ID: urn:471a82cfa75909b638edc4598ec22e90
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Retrofit Solutions for Residential Buildings

General information
State: Published
Organisations: RWTH Aachen University
Authors: Calì, D. (Intern), Osterhage, T. (Ekstern), Müller, D. (Ekstern)
Number of pages: 6
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Main Research Area: Technical/natural sciences

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Journal: International Journal of Sustainable Building Technology and Urban Development
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Source-ID: urn:9c0473adb0b39d0ce91d320508e5b7a5
Publication: Research - peer-review › Journal article – Annual report year: 2011

Simulation models of refurbished residential housing: validation through field test data

General information
State: Published
Organisations: RWTH Aachen University
Authors: Calì, D. (Intern), Osterhage, T. (Ekstern), Constantin, A. (Ekstern), Müller, D. (Ekstern)
Publication date: 2011

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Title of host publication: CISBAT 2011 : Cleantech for sustainable buildings ; from nano to urban scale : proceedings
Field study of different retrofit solutions for residential housing: Contribution to a conference proceedings

General information
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Organisations: RWTH Aachen University
Authors: Calì, D. (Intern), Osterhage, T. (Ekstern), Müller, D. (Ekstern)
Publication date: 2010

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Systematische Untersuchung von Sanierungsmaßnahmen für Wohngebäude der 50-er und 60-er Jahre: Contribution to a conference proceedings

General information
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Authors: Osterhage, T. (Ekstern), Calì, D. (Intern), Müller, D. (Ekstern)
Publication date: 2010

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Title of host publication: BauSIM 2010 Building performance simulation in a changing environment: proceedings of the third German-Austrian IBPSA Conference